Abu Dhabi University

EEN 340 - Energy Conversion

Research Project
Micro-scale Applications for Generating Electricity

Author:
Muhammad Obaidullah 1030313

Supervisor:
Dr. Muhammad Akmal

Section 1

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Abstract

In this research, I discuss some of the small scale electricity generating schemes such as wind turbines and solar panels and how to successfully operate and maintain these applications/schemes. The basic structure for small scale electricity is also outlined, giving the most fundamental circuit block diagram and energy flow diagram. The basic techniques for power storage and consumption is also outlined.

1 Introduction

The continuous increase in electrical power demand pushes on-going researches to further explore the power generation techniques at different scales. Micro-scale applications for generating power deals with generating electricity for small scale usage such as for homes or offices and storing the surplus power for either later use or injecting it into a larger network to support peer. The generation is classified as Micro-scale when the generated power is about 6 KW for single phase connection and about 11 KW for three phase connection because 3 phase generation is more efficient than single phase.[3]

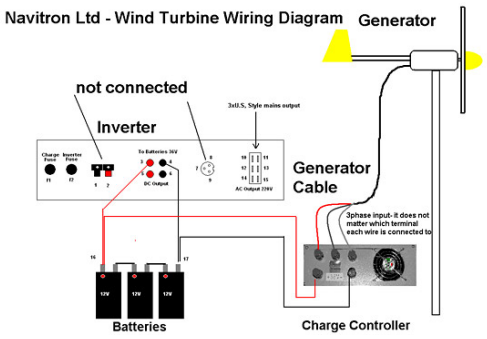

Figure 1: A classical wind turbine wiring diagram for usage in small scale electricity generation.[4]

However, there are some blessings and drawbacks for usage of small scale electricity generation. Some drawbacks are that usually the power generation is not enough to meet the power demand, high initial capital cost, and noisy operation. The blessings include high portability of the system, and usually are environment friendly.

Micro-generation of electricity techniques range from small scale wind turbines, hydro turbines, solar panels, to ground source heat pumps. Wind turbines use wind power to generate electricity for small scale applications while hydro turbines harvest the energy from flowing water in the river or small dams. Additionally, solar panels harvest the renewable energy from the heat of the sun and deliver electrical power. And finally, ground source heat pumps use the heat of the land nearby to warm fluid which in turn runs the turbine for electricity generation. [1]

There are several ways energy can be harvested to make electricity, some of these methods are more greener than the others but all methods should follow the same basic structure described in the *next section*.

2 Basic Structure of Micro-Scale Electricity Generation

First, a mechanical power is converted to electrical using a turbine. A turbine is basically a rotor attached to specially designed fins/blades to harvest maximum energy from a fluid. Fluid pressure on turbine causes the rotor to rotate and this rotary motion causes the permanent magnet/-electromagnet present inside the stator windings to rotate which induces current into the stator windings. If the stator windings are wound like a 3-phase machine, the output electricity will be three phase. On the other hand, if the windings are wound in the single phase manner, then the output electricity will be single Phase.

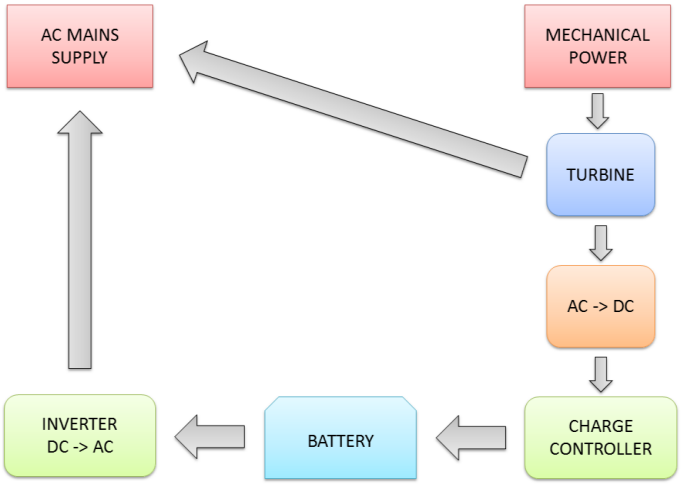

Figure 2: Copyright Muhammad Obaidullah 2013

Second step is to store this energy and Alternating Current cannot be stored in batteries. Rather, we need to convert it into Direct Current so that electron flow is unidirectional. The need to convert AC to DC arises because the batteries store electricity as chemical energy. There are two separate cells inside a typical battery. One cell contains chemical rich in electrons and the other cell contains chemical rich in holes. As a electron path is formed (conductor is connected) the electrons flow from one chemical to another. Since, the current is flow of electrons, current flows in the circuit.

Third step is taken when AC electricity is needed by the user. Inverter converts the DC power stored in the battery to AC by means of complex electronic oscillating circuit. This might be considered as a disadvantage of the system as power is lost when inverter converts from DC to AC.

3 Wind Turbines

The usage and existence of wind turbine has enormously increased after renewable energy campaign. Wind turbines convert wind energy to useful electrical power. The wind swooshes over the rotor of the wind turbine and causes it to rotate. This rotating motion causes change of flux inside the stator windings which induces Alternating current in the stator windings.

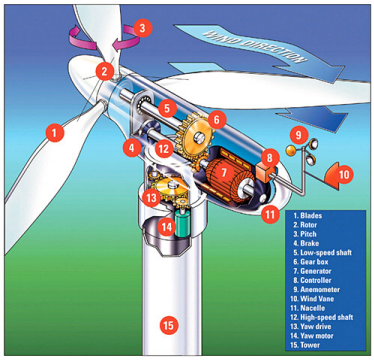

Figure 3: The basic structure of a wind turbine showing internal structure and parts in detail. [7]

Wind turbines range in size from small rooftop turbines generating electricity for household usage to large industrial wind turbines generating power in Mega Watt range. It is customary that a large group of wind turbines are established in an area which is known to have high speed of wind. This area is known as Wind farm.

The total worldwide capacity of installed wind turbines in 2008 was 121 Giga Watts and this is just 1% of total power generation.[6]

A wind turbine should be planted at the areas where there is high speed of winds atleast half of the time in year otherwise the efficiency will greatly be reduced. The slightly cold and open regions are perfect for wind power harvesting as the wind flow in open areas is high and large area is available. The problem with these areas might be that often these areas also support optimum agricultural nutrients for farming. The coastal areas are also optimum for wind farms as the cool sea breeze is present in the day and the reverse at night. In New Zeland, large areas of wind farms are present in combination with agricultural farming.

The major electrical milestone for a wind turbine is to solve the frequency deviation problem due to variation in wind speeds. The wind speed varies significantly which in turn can affect the rotational frequency of turbine resulting in variable frequency electricity. To solve this problem, gears are used to step-down or step-up the rotational frequency of the turbine.

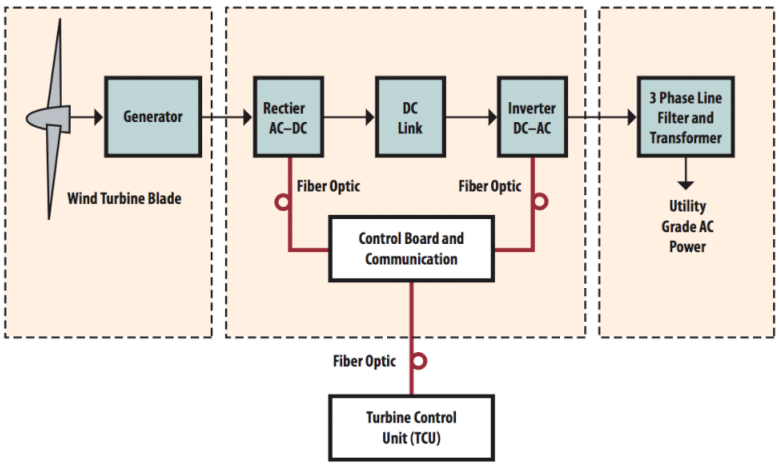

Figure 4: An overview of the windturbine system.[11]

4 Small Scale Solar Panels

One of the modern technological advancement in this modern era is the introduction of solar panels in Micro-scale applications for generating electricity. Solar panels are ideal for regions which usually experience high temperatures during most part of the lunar calendar. Solar energy harvesting is booming in most regions of the world due to its economical and environmental friendly features outweighing the current techniques used for generating electricity.

Figure 5: Sony has unveiled a transparent see through solar panels which can be used for small scale electricity generation [8]

Solar panels or photovoltaic contain silicon wafer cells which produce electric voltage when stuck by sunlight. There are two problems regarding the voltage produced, the voltage is very less and is DC in nature. So it can be used for small power usage such as night bulbs and small fans. hybrid systems are also in use which use small amount of power generated by solar panels for low power appliances and the portion of energy is injected into the main system for aiding in power supply.

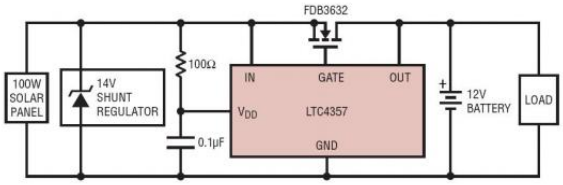

Figure 6: Solar Panel charging a 12V battery and preventing back feeding. Back feeding is when the battery starts to supply power to the solar panel rather than absorbing power. This circuit prevents that from happening and charges the 12V battery in a safer way. [10]

In order to store all the harnessed power efficiently into the battery for later use, a safe and efficient charger circuit should be employed. Normal diodes and transistor circuit is not efficient enough because it dissipates huge amount of power in the transistor and large heat sinks are required to keep the transistor in cool temperature. The circuit should also be able to cut-off the supply to the battery in case of an overcharge. The charger circuit is usually readily available in the market but its cost increases proportionally with the complexity of the circuit.

5 Conclusion

- Advantages and disadvantages of small scale application for electricity generation was discussed.
- Solar panels need sunlight for operation but can only generate upto 15V at maximum sunlight. This voltage is not ideal for high power appliances but is good and efficient for low power appliances like LED light bulbs and low power fans.
- For small scale electricity generation, a power efficient controller circuit should be designed which can lead to increased cost depending on the complexity of the circuit.
- Wind turbines are region specific as they required medium to high speed winds to operate.
- This research concludes that the initial capital cost for small-scale power generation can be high but the long-term advantages outweigh the initial cost.

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